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TREATMENT OF MISSOURI RIVER WATER AT COUNCIL BLUFFS, IOWA¹

By J. B. THORNELL

The method of purification in practice at the Council Bluffs city water works is that of coagulation and sedimentation followed by treatment with chlorine for the destruction of bacteria. This process has been used quite extensively for a number of years, so that its operation and effect are familiar to all who take an active interest in water purification. But, although the same general plan of procedure may be in use in many places, there are so many things which may influence its conduct that each plant has its own difficulties and interesting peculiarities.

The water is lifted from the Missouri River into the first group of three settling basins (fig. 1), which have a combined capacity of 8,400,000 gallons. Between basin 1 and basin 2 is a weir 45 feet long, over which the water flows in a sheet about 3 inches deep. The lime and alum used as coagulants are added at this weir. The water passes over a submerged wall between basins 2 and 3. It leaves basin 3 through a jointed pipe, the mouth of which is held within 18 inches of the surface by a float. From basin 3 it proceeds by gravity to the Broadway plant, about one-half mile south of the river plant.

At the Broadway plant is another group of three settling basins; which have a combined capacity of 13,500,000 gallons. As it leaves the last of these basins it receives a charge of chlorine before being pumped into the distributing main.

The clarification of the water is the most difficult as well as the most important part of the process. The greatest trouble is encountered early in the spring. The water thrown into the river by the melting of snow and rains in March and April carries with it a great deal of vegetable stain and light suspended matter which is exceedingly hard to remove. The chemical nature of the raw water at

¹ Paper read before a joint meeting of the Iowa and Illinois Sections at Davenport, Iowa, on October 10, 1916.

this time undergoes rapid and wide changes. The organic content is greatly increased. The alkalinity takes a sudden drop and the suspended matter, although its amount is not so great as is usually

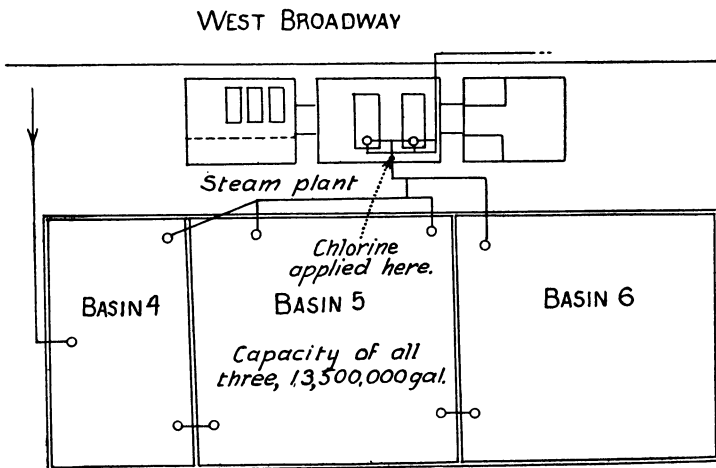
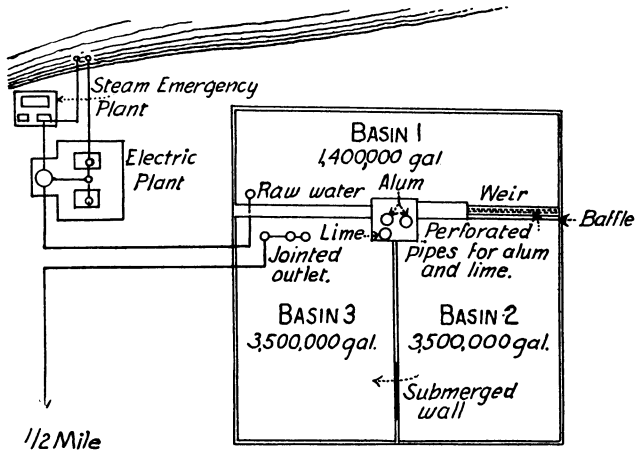


FIG. 1. SCHEME OF PURIFICATION PLANT

found later in the spring and summer, carries an enormous number of bacteria.

The most unusual change of this nature which we ever observed came in February and March, 1915. A period of warm weather

and rain melted the snow, which was unusually heavy that winter, and thoroughly flushed the surface of the ground for the first time in three or four months. The change was so sudden that an immense volume of soft water laden with silt, bacteria and organic matter rushed into the river. The organic content of the raw water increased 300 per cent and the alkalinity decreased 50 per cent. The coagulating action of the alum was almost completely destroyed, for it was combining with the organic matter in the water instead of forming the flocculent hydroxide. Our tap water became very turbid and it was necessary to add an excess of calcium hypochlorite solution as a safe guard against harmful bacteria. We were using alum alone for coagulation at that time but this experience convinced us that it was inadequate under such conditions. Hasty preparations were made for the use of hydrated lime as an adjunct to the alum. The lime solution was injected at the intake line of the low-service pumps which lift the water from the river into the settling basins. This arrangement was a great aid in the removal of suspended matter during the remainder of the trying period of high water, but the apparatus was crude and there were great disadvantages in applying the solution in the suction line of the pumps. This part of the treatment was, therefore, discontinued after a few months and experiments were begun toward perfecting better apparatus and finding the most advantageous point of application.

We are now adding the lime to the water at the weir between basin 1 and basin 2 through a perforated pipe extending over the entire length of the weir. The device for feeding the lime is located in the gate house near the weir. A large iron hopper is filled with dry lime. In the bottom of the hopper is a worm which pushes it into a smaller, funnel-shaped hopper below. A stream of water flows into the lower funnel dissolving the lime and carrying it out through a 2-inch pipe to the weir. A small electric motor drives the feeding device and is also attached to a small centrifugal pump which draws from one of the settling basins the water for dissolving the lime. By an arrangement of pulleys and gears the speed of the worm may be regulated as desired. About 30 gallons of water are used for each pound of lime. The large volume of water used is one of the main factors in the success of the treatment, because it completely dissolves the lime, thereby preventing clogging of pipes and bringing about thorough mixing of the lime solution with the raw water before it receives the charge of alum solution.

The alum solution is applied through a second perforated pipe immediately after the lime solution. The amount of alum required varies between 1 and 3 grains per gallon and the amount of lime varies between $\frac{1}{2}$ and $1\frac{1}{2}$ grains per gallon of water treated.

Comparison of the available data on the turbidity of the settled water and of the water at the point of application of the coagulants, and calculations of the costs of coagulants before and since the use of lime as an aid to alum was commenced, show that a much better quality of water has been obtained by the use of lime with the alum and that it is more economical than the use of alum alone.

A glance at the accompanying table gives a fair idea of the results obtained by the use of lime with the alum from April 1 to September 1, 1916, as compared with those obtained by using alum alone during the same months of 1914. In 1916 the raw water contained 17 per cent more suspended matter than in 1914. The turbidity of the settled water was reduced 81 per cent and the comparative cost of coagulants was 11 per cent less in 1916 than in 1914.

Comparison of turbidities and cost of coagulants, April 1 to August 31, 1914 and 1916

MONTH	TURBIDITY OF WATER AT POINT OF APPLICATION OF COAGULANTS. PARTS PER MILLION				AMOUNTS OF COAGULANTS USED. GRAINS PER GALLON				TURBIDITY OF SETTLED WATER. PARTS PER MILLION				COST OF COAGULANTS PER MILLION GALLONS.* (BASED ON 1914 PRICE OF ALUM)			
	1914		1916		1914		1916		1914		1916		1914		1916	
			Increase	Decrease												
			per cent	per cent	Alum	Lime	Alum	Lime			Increase	Decrease			Increase	Decrease
April.....	1212	2222	83		2.3	0	2.4	1.1	6	2		66	\$3.19	\$3.88	21	
May.....	1299	1078		20	2.9	0	1.2	1.2	5	1		80	4.03	2.27		43
June.....	1695	1196		29	3.1	0	1.8	1.1	11	2		81	4.30	3.05		29
July.....	1506	1873	24		2.5	0	2.2	1.3	24	2		91	3.47	3.70	6	
August.....	758	1248	64		2.0	0	1.8	1.1	8	2		75	3.05	3.05		
Average....	1294	1523	17		2.6	0	1.8	1.1	11	2		81	3.61	3.19		11

* Alum (1914), \$9.75 per 1000 pounds; lime, 1916, \$3.50 per 1000 pounds. (These prices do not include freight.)

Due to three hours' natural sedimentation in basin 1, the water as it passes over the weir has an average turbidity which is only 35 per cent of the average turbidity of the raw water. Experiments in the laboratory and actual experience at Council Bluffs show that

in the clarification of water carrying such great quantities of suspended matter as are found in the Missouri River water a great saving in the cost of coagulants can be brought about by allowing ample time for natural sedimentation before adding the coagulants. This fact is clearly shown in the table.

The upper three curves in figure 2 show the stages of the river in feet above low-water mark, the turbidity of the raw water and the number of bacteria per cubic centimeter of raw water. It is readily seen that the three curves follow one another quite regularly. The only noticeable divergence from the usual course is shown in the very marked increase in the number of bacteria in the raw water in January and February, 1916. Our record of local weather conditions shows that unusually warm weather prevailed for three different periods in those two months, but the changes in temperature, evidently, were not general enough to affect the turbidity of the river, although they were sufficient to cause a moderate rise in the river stage. The highest counts of bacteria in the raw water are found early in the spring, although the turbidity and stage of the river do not reach their highest points until June or July. From this it would seem to be a reasonable conclusion that the most of the bacteria found in the water at that time are soil bacteria which are generally classed as non-pathogenic.

Figure 2 also gives curves for the alkalinity and total hardness of the tap water in parts per million. The alkalinity and hardness follow each other quite closely but both vary inversely as the river stages. Judging from these curves it would seem that the amount of dissolved mineral matter which is carried past a given point on the bank of the river does not vary greatly from month to month but that the variation in alkalinity and total hardness are caused principally by greater or less dilution.

As shown in figure 3 the number of bacteria in the settled water before chlorine treatment and the turbidity of the raw water are inversely proportional to each other. This point emphasizes the great importance of the process of clarification. The coagulation and sedimentation of the suspended matter remove mechanically from 85 to 99 per cent of the bacteria.

After passing through the settling basins the water is treated with chlorine for the removal of bacteria. The use of liquid chlorine was commenced in March, 1915. The amounts of chlorine required have varied between 0.2 and 0.3 part per million and the average amount

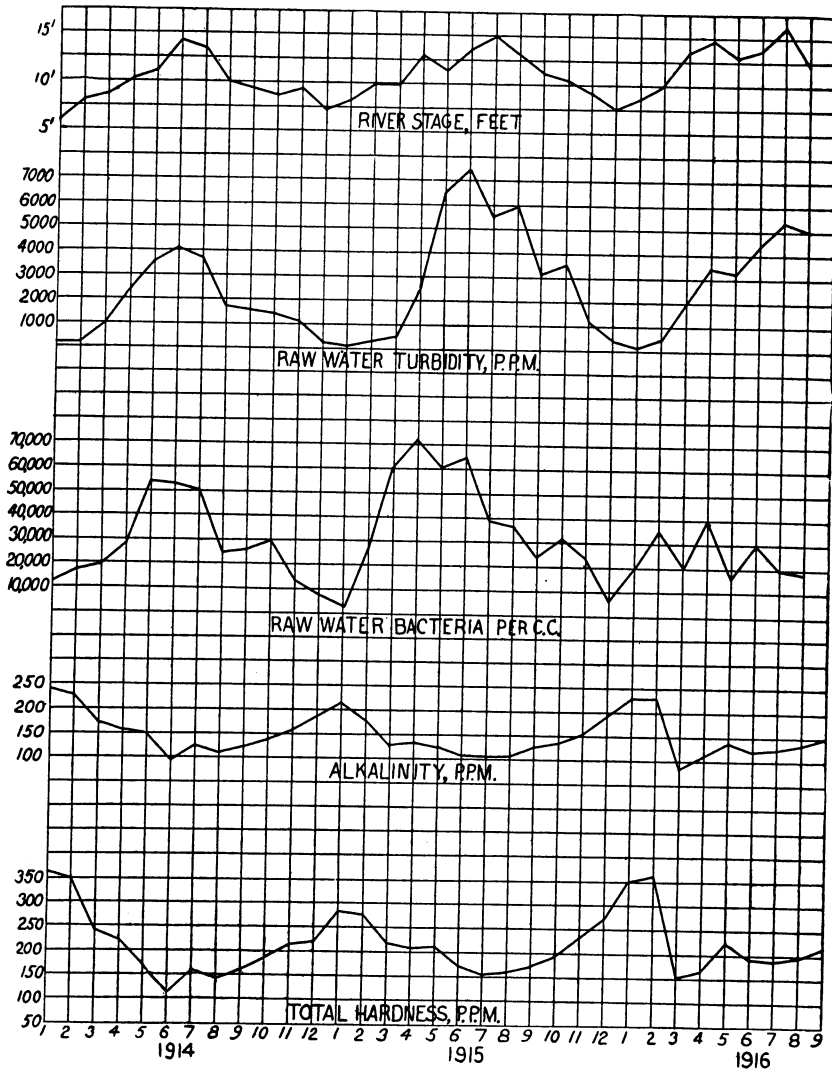


FIG. 2. RIVER STAGES, TURBIDITY AND BACTERIA IN RAW WATER, AND ALKALINITY AND TOTAL HARDNESS OF TAP WATER

was 0.247 part per million or 33 ounces per million gallons of water treated. Including freight on the cylinders the chlorine has cost about 11 cents per pound or $22\frac{1}{2}$ cents per million gallons of water. Previous to the installation of the liquid chlorine apparatus, calcium hypochlorite in the amount of about 8 pounds per million

gallons of water was used for sterilization. That was before the war price was put on bleach. Including freight it cost a little less than $2\frac{1}{2}$ cents per pound or about 20 cents per million gallons of water treated. This means that the use of liquid chlorine has made no marked change in the cost of sterilizing reagent in normal times.

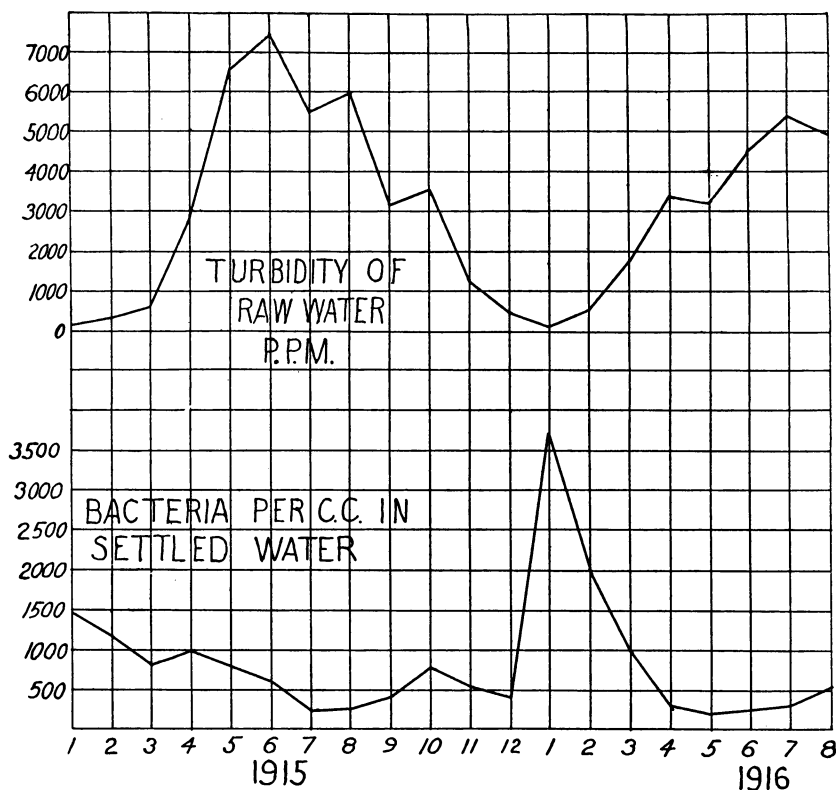


FIG. 3. TURBIDITY OF RAW WATER AND BACTERIA IN SETTLED WATER

The greatest advantages derived from the use of liquid chlorine in sterilization are in the ease of operation and the steadiness of the treatment. We have found that our chlorine apparatus can always be depended upon, whereas we were almost constantly troubled with clogging of pipes and a great inconvenience in handling the hypochlorite.

The average counts of bacteria in the tap water have not shown any marked change since the use of liquid chlorine was commenced.

For the first eight months of 1916, the average number of bacteria in the tap water was 48 per cubic centimeter. During the same eight months of 1914 when hypochlorite was in use the average was only 31. This difference is partly explained by the fact that in the summer of 1916 copper sulphate was used from time to time for the destruction of algae in the settling basins and that treatment was always followed by high counts of bacteria in the settled and tap water. The bacteria which increased so rapidly after the copper sulphate treatment seemed to be quite resistant to chlorine but they are harmless soil bacteria and of little or no importance to the sanitary quality of the water.

The presumptive tests for *B. coli* in the tap water in the past eight months have given positive results in only 3 per cent of the samples tested. There are still improvements to be made and economic measures to be investigated in connection with the treatment. Our system and the quality of the supply lack much of being perfect. The softening of the water during the winter months; more effective baffling of the water; a longer period of natural sedimentation before the addition of the coagulants; a more satisfactory treatment for the destruction of algae; and the home manufacture of alum are some of the things which must be investigated and each must be taken in its turn. Up to this time our attention has been occupied by matters which pertained principally to making the supply *safe* and *wholesome* and as nearly constant in quality as possible. Our efforts must now be turned more particularly to matters of economic efficiency.